Are architectural traits at flowering stage relevant to account for yield advantage in hybrid rice?

Previous studies reported that the yield advantage of hybrid rice over conventional inbred is attributed to higher biomass production due to higher seedling vigor and higher harvest index (HI). Their yield advantage is at least 10-15% under tropical favorable environments. Getting a better understanding of hybrid rice superiority in terms of morphological and physiological characteristics is important to guide breeding programs and plant-type management. Thus, precise phenotyping of high-yielding hybrid rice and inbred lines with the same crop duration was done to quantify dynamics in assimilate partitioning and architectural plasticity in response to canopy competition.

Materials and methods

Field experiments were laid out in a randomized complete block design with four replications in 2004 and 2005 at the IRRI experimental farm, Los Baños, Philippines. Hybrids (H) and inbreds (I) with same crop duration were compared; IR72 (I1) and IR75217H (H1) in 2004 dry season (DS); two inbreds, IR72 (I1) and IR77958-14-4-7 and two hybrids, IR75217H (H1) and IR78386H (H5) in 2004 wet season (WS); and IR72 (I1) and SL-8 (H3) in 2005 wet season. Seeds were sown in seedling nurseries at the rate of 3,000 seeds m^{-2} and were transplanted after 7 d with one seedling $hill^{-1}$.

Results

Grain yields of H1 and H5 were significantly higher than those of I1 and I10 by up to 15–20%, in the wet season, and up to 32% higher in the dry season, when considering genotypes with similar crop duration (Table 1).

Table 1. Differences in mean grain yield (GY), shoot dry weight, panicle density, filled grain number, and harvest index (HI) of the different genotypes. *Means followed by a common letter are not significantly different at P≤ 0.05 based on LSD.*

Genotype	GY t ha^{-1}	Shoot DW, kg m^{-2}	Panicle density, m^2	Panicle DW, g prod $tiller^{-1}$	Filled grain no., g m^{-2}	HI
Dry season, 2004						
H1	9.1 a	1.95 a	473 b	2.37 a	43358 a	0.53 a
I1	6.9 b	1.93 a	554 a	1.86 b	39790 a	0.46 b
Wet season, 2004						
H1	6.1 a	1.71 a	409 a	2.20 a	31445 a	0.48 a
I10	5.4 ab	1.60 a	402 a	2.03 b	28939 a	0.46 ab
H5	6.2 a	1.93 a	439 a	2.36 a	36641 a	0.51 a
I1	5.2 b	1.69 a	484 a	1.69 c	30203 a	0.43 b
Wet season, 2005						
H1	6.8 a	1.17 a	256 b	2.31 a	20360 a	0.46 a
I1	6.4 a	1.10 a	300 a	1.40 b	15921 a	0.38 b

The superiority in yield of the hybrid was systematically associated with higher harvest index (HI) in the dry and wet seasons. Higher panicle dry weight and higher filled grain number in hybrids appeared mostly as a compensation for the lower panicle density (Table 1).

Early seedling vigor was similar for H1 and I1: dynamics in shoot dry matter, leaf area index, and specific leaf area (SLA) did not significantly differ between the genotypes at least until 50 days after sowing (DAS) whatever the growing season (Fig. 1). Early seedling vigor was also similar between H5 and I10 during the wet season (data not shown). Increase in shoot dry weight during grain filling was, however, appreciably higher in the hybrids than the inbreds.

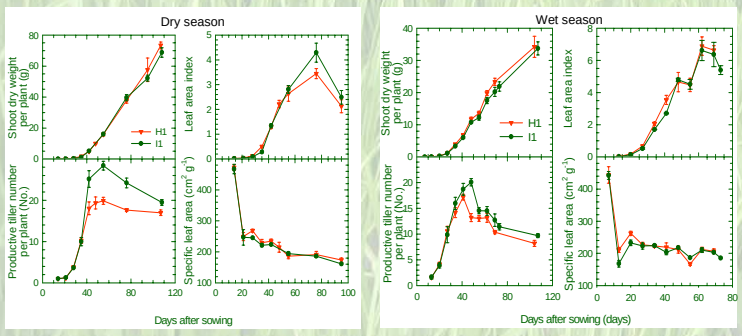

Fig. 1. Dynamics in shoot dry weight, productive tiller number, leaf area index, and specific leaf area (SLA) of H1 and I1 in the dry and wet seasons of 2004.

The internode dry weights of the hybrids increased faster than those of I1 even if the start in elongation was simultaneous for both plant types (Fig. 2). In the same way, after panicle initiation, the partitioning coefficient for internode was higher, and that for the blade was lower in H1 compared to I1 (Table 2). As a consequence, the final internode dry weight of hybrids was reached earlier than in I1, for which tiller production was extended (Fig. 1).

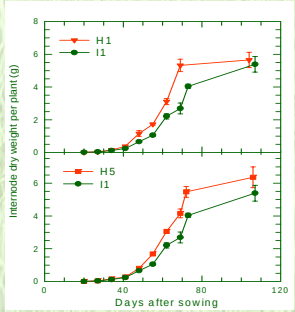

Fig. 2. Dynamics in internode dry weight of H1 and H5 as compared to I1 in the wet season of 2004.

Table 2. Partitioning coefficients (%) for the different plant organs at 58 DAS among the different genotypes.

Genotype	Blade	Sheath	Internode	Panicle
Dry season				
H1	13	32	33	22
I1	46	39	13	2
Wet season				
H1	15	13	34	38
I10	24	25	29	22
H5	26	27	30	17
I1	31	32	25	12

Architectural arrangement in plant canopy appeared to be more efficient for hybrids than for inbreds from panicle initiation: hybrids exhibited a higher stem elongation rate (Figure 2), a quicker decrease in blade angle with the main tiller and a constant ellipse formed by the leaf area of the hill at the highest plant collar level (Fig. 3).

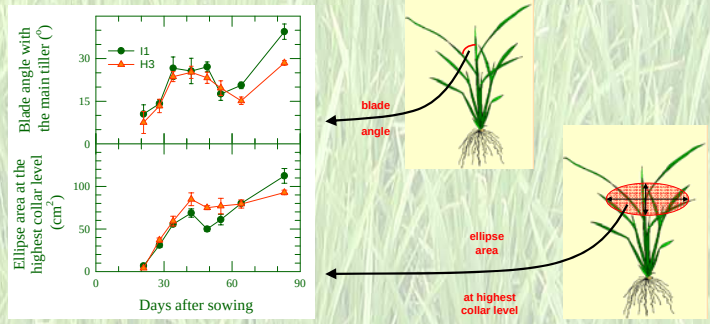

Fig. 3. Dynamics in blade angle of the main tiller and ellipse formed by the leaf area of the hill at the highest plant collar level of H3 and I1 in the 2005 wet season.

Conclusion

Two strategies observed with the hybrids could explain most of their superiority in terms of grain yield. First is their ability to grow internodes faster; thus to partition earlier most of the newly gained assimilate to the grain while the internodes are still elongating in the inbreds. Second is their ability to set up an efficient architectural arrangement, thus light distribution in the canopy is improved and light interception increases.

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